TRANSMISSION CHARACTERISTICS OF KERR CELL SHUTTER

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The use of Kerr shutters in shadowgraph systems as one solution to the dual problem of image blurring and self-luminosity of a high-speed test model has been pursued at Ames Research Center and has been reported briefly at a prior meeting. Some of the problems encountered in using Kerr cell shutters and solutions realized in the installation of a new system will be discussed here. Initial photographs taken with the newest Kerr cells in the optical train produced photographic exposures with much lower contrast than expected. Thus an investigation of the light-transmission properties of the installed Kerr shutters was made.

These Kerr shutters consist of: (a) a fused quartz cell containing (b) a Kerr liquid (benzonitrile) placed between (c) two Glan-Thompson crystal polarizers. The purchase specifications requested total trnsmissive properties of 40 percent in the 3200-8000 Å spectral range.

The components used to measure the transmission properties of the Kerr shutter optical elements were a deuterium light source, a grating monochromator, and a photomultiplier tube with assorted electronic equipment. The various elements of the shutter, as well as the complete shutter, were inserted in the light path in such a manner that no vignetting of the beam accepted by the monochromator occurred. The ratio of photomultiplier output voltages with and without the shutter element in the light beam was taken as the transmissivity of the element at specific wavelengths.

[redacted]

Kerr shutter serial no. 138 was selected at random for the tests. Measurements of the continuously open shutter (polarizers aligned) gave approximately 40 percent transmission above 6000 Å wavelength; transmission decreased with decreasing wavelength, particularly between 4000 and 3500 Å (see Fig. 1). Also shown is the transmission of the polarizing elements only. The difference between the two curves illustrates that the short wavelength transmission cutoff is the result of either the quartz cell or the Kerr liquid.

Figure 2 illustrates the transmission properties of a sample of the original benzonitrile used in the filling of the shutters. Also shown is the transmission of the cell and Kerr liquid from shutter no. 138 and the manufacturer's published specifications for pure benzonitrile. The sample exhibits transmission characteristics in fair agreement with the specified transmission characteristics as furnished by the contractor.

The transmission of the vycor container used in this test was constant in this spectral range, and agreed well with the transmission characteristics of an empty shutter cell.

It is apparent that the benzonitrile has been somehow degraded in the Kerr shutter manufacturing process to produce an additional transmission loss at the shorter wavelengths.

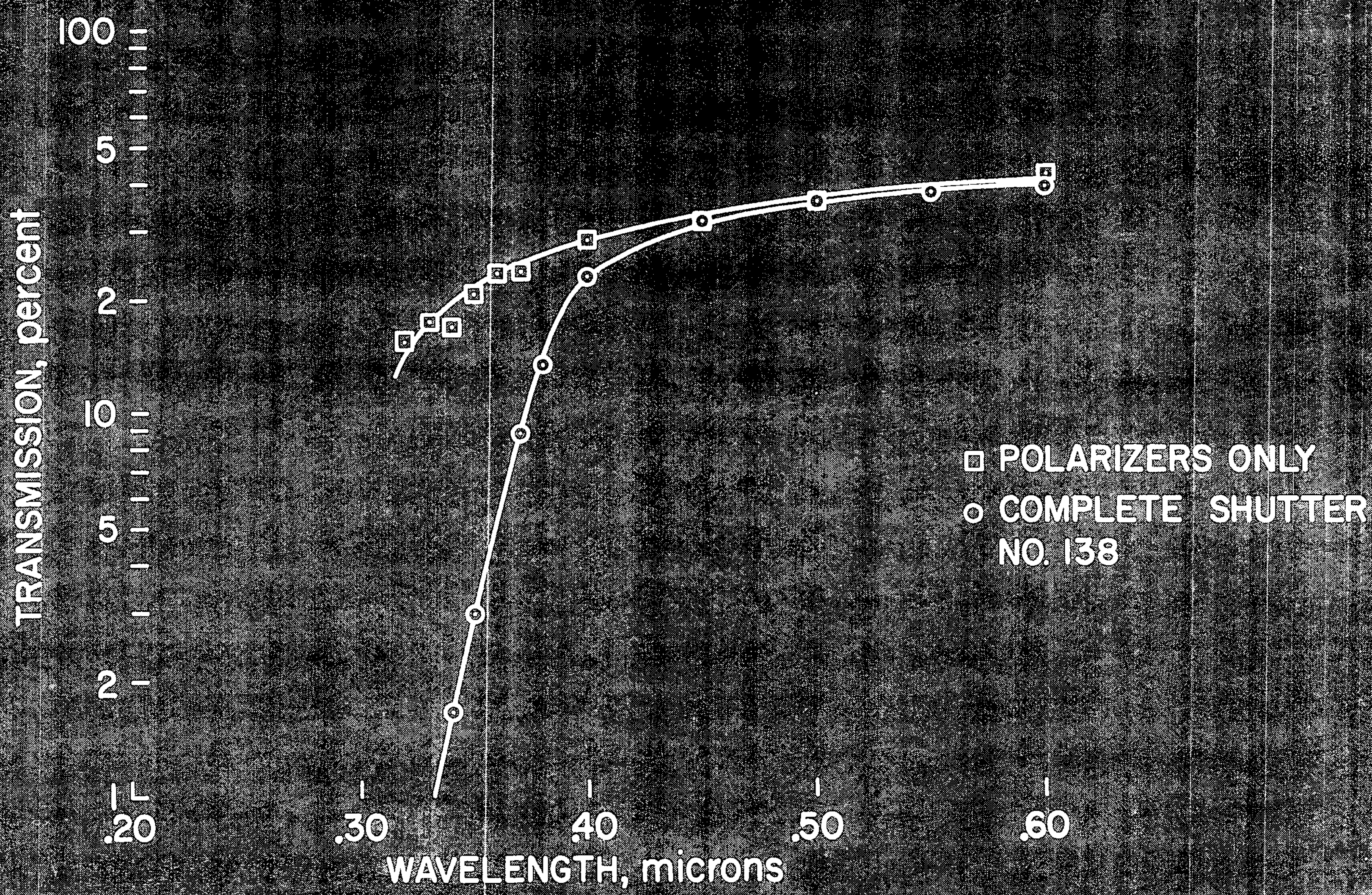
The importance of the unexpectedly poor transmissivity of the Kerr shutters in the ultraviolet spectral range can be appreciated if the relative energy passed through the entire shadowgraph system and available for film darkening is expressed as a function of wavelength. Calculations were made for three cases: Case 1 for the system, as operated initially with shutter no. 138; Case 2 with a Kerr shutter transmission characteristic that would result from refilling the cell with the original sample benzonitrile, assuming no degradation; whereas Case 3 refers to our purchase contract specifications for Kerr shutter transmission.

The relative energy W_λ is the product of the spark relative spectral emittance, transmissivity of the glass window of the facility, the response of the film, and Kerr cell transmissivity, and is plotted as a function of λ in figure 3. The ratio of areas beneath the curves for the different cases is a direct measure of the relative film darkening that would occur for the three cases. The refilled cell will increase the film exposure by about a factor of two, whereas a Kerr cell built to our contract specifications would have increased the exposure by about a factor of four. It is anticipated that an improvement of a factor of two in contrast will produce negatives comparable to those obtained in our prototype Kerr shutter installation.

The contractor is at present investigating the problems and possible solutions to the apparent benzonitrile contamination. The application of Kerr shutters in the prototype facility has proved to be a practical addition to our shadowgraph systems. The light transmission loss introduced is not unreasonable and the rejection of model self-luminescence is marked, as is shown in figure 4. Part (a) of the figure is an unshuttered focused shadowgraph with the model image almost completely obliterated by self-luminescence. Here, the pinhole in the spark image plane (used to reject model self-luminescence as much as possible) is about 1/8 inch in diameter.

Smaller diameters, leading to greater rejection, are not practicable because of lack of total mechanical rigidity of the shadowgraph system components. Part (b) is a shadowgraph taken of the same model using a Kerr cell shutter with an exposure time of 25 nsec.

KERR SHUTTER AND COMPONENT TRANSMISSION



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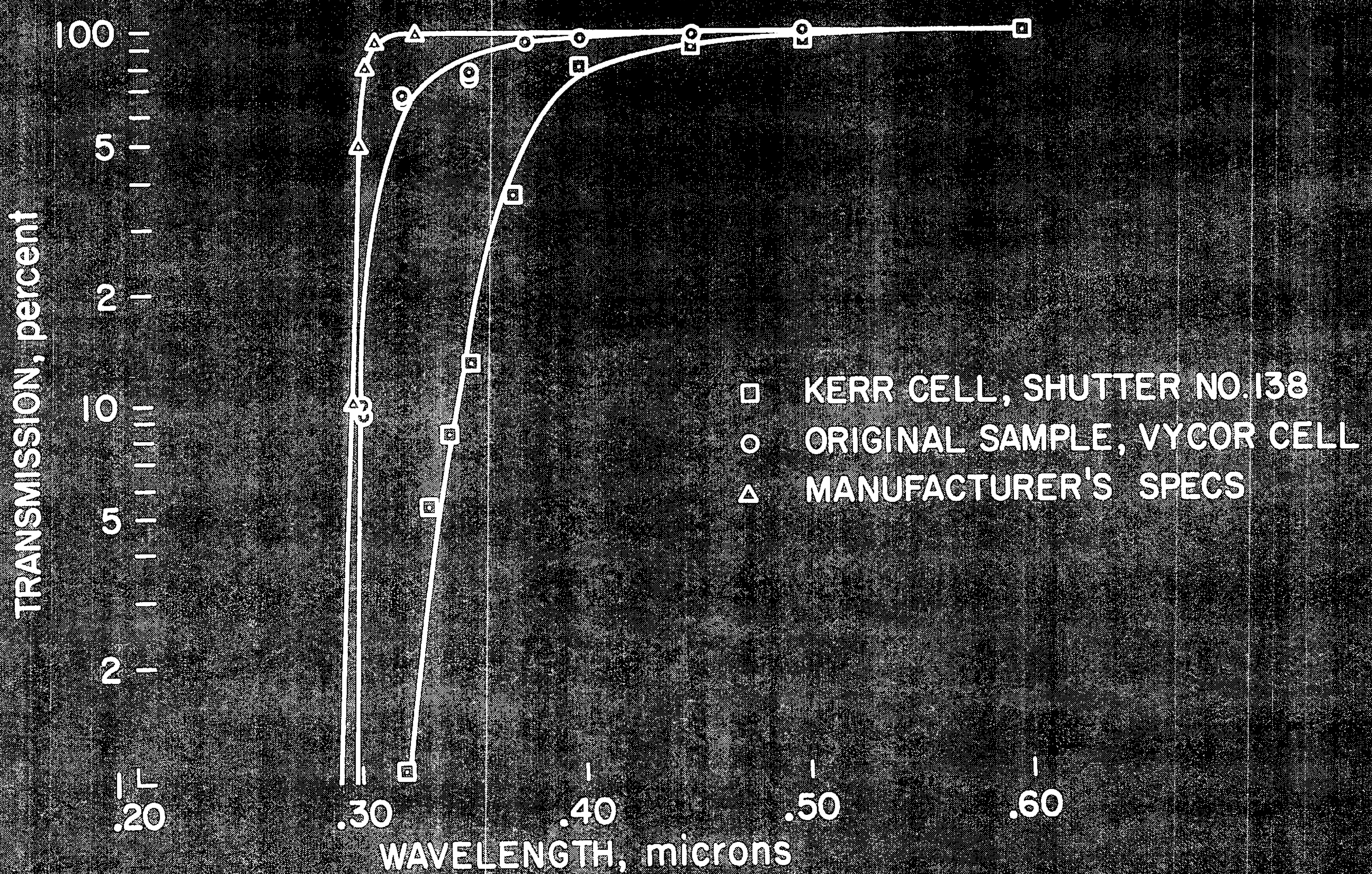
ULTRAVIOLET TRANSMISSION OF BENZONITRILE



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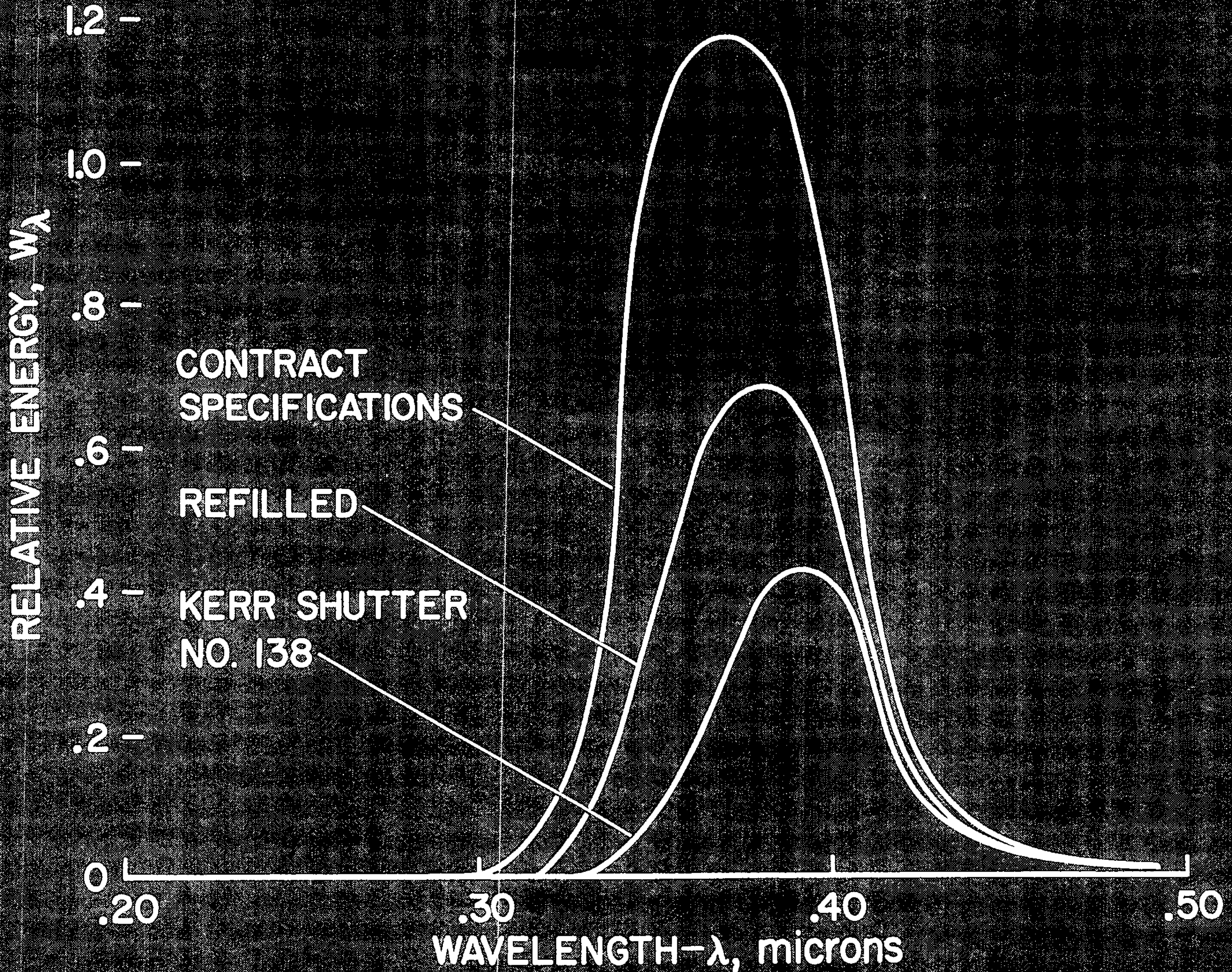
COMPUTED ENERGY AVAILABLE FOR FILM DARKENING



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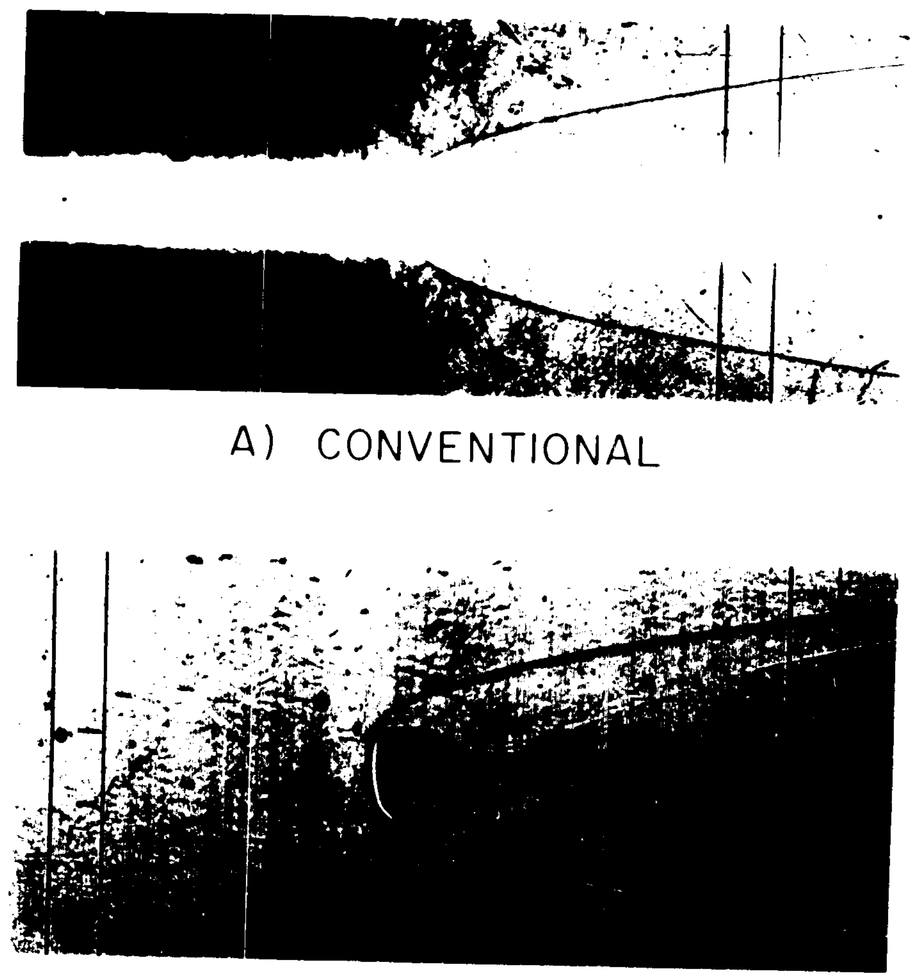
SHADOWGRAPHS OF HALF-INCH LEXAN MODEL

$\rho/\rho_0 = 0.129$ $V_\infty = 9.53$ km/sec



A) CONVENTIONAL

B) KERR CELL SHUTTERED

Fig 4